

An analysis of laser distance measuring by different laser rangefinders

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Abstract. Laser rangefinders have emerged as indispensable tools in various fields, enabling accurate distance measurements through the utilization of laser technology. This paper provides a comprehensive overview of laser rangefinders, including the principle of laser rangefinders, classification, practical applications, and calibration methods. Different types of laser rangefinders are discussed based on their operating principles, while the various fields in which laser rangefinders are widely used are highlighted. The importance of accurate calibration is also discussed in depth, and the various techniques used to calibrate laser rangefinders are explored. In addition, accuracy and measuring range of each kind of laser rangefinder will also be discussed. This paper aims to provide a comprehensive understanding of laser rangefinders, including their classification, practical applications, and calibration methods. It also highlights the importance of accurate distance measurements in various industries and the role of laser rangefinders in meeting these requirements.

Keywords: Laser rangefinder, Principles of rangefinders, Classification of rangefinders, Calibration and Application

1. Introduction

Laser distance measuring uses a laser as the light source for distance measuring. The lasers are classified into continuous lasers and impulse lasers according to the pattern of working. Helium neon, argon ion, krypton cadmium and other gas lasers operate in a continuous output state and are used for phase laser measuring. And dual heterojunction gallium arsenide semiconductor laser for infrared measuring, solid state lasers such as ruby and neodymium glass for pulse laser ranging. Due to the characteristics of good monochromaticity and strong directionality of laser, as well as the semiconductor integration of electronic circuits, laser rangefinders can not only operate for a long period, but also operate accurately.

There are three main categories of laser rangefinders which are respectively hand-held laser rangefinder, telescope rangefinder, and industrial laser rangefinder. The measures for different rangefinders are different from each other as well. They are based on different principles, so in the following paper the laser rangefinders will be categorized and introduced in three aspects. In all, laser rangefinders have revolutionized distance measurement by utilizing laser technology. They offer numerous advantages, such as high precision, fast response time, and non-contact measurement capabilities.

2. Classification of Laser Rangefinders

In this section, it is mainly analyzed from application-based classification, and design-based classification.

2.1. Application-based Classification

The application-based classifications are as follows:

2.1.1. Industrial Application: Laser rangefinders find applications in manufacturing, engineering, and quality control processes, which are used for precise measurement and alignment of components, ensuring efficient production processes.

2.1.2. Construction and Architecture. Laser rangefinders are used for layout and measurement tasks for accurate construction processes. They determine distances, angles, and heights for architectural design and planning. For example, integration of laser rangefinders in a construction site for precise measurement and alignment [1].

2.1.3. Surveying and Mapping. In the field of surveying and mapping, laser rangefinders are used for land surveying, topographic mapping, and GIS applications. They enable accurate measurements of distances, elevations, and coordinates for surveying and mapping purposes. They provide precise distance measurements, enabling surveyors to accurately determine the position and elevation of points on the earth's surface [2]. Laser rangefinders are commonly employed in topographic surveys, construction layout, and boundary marking. For example, implementation of laser rangefinders in a large-scale land surveying project [3].

2.1.4. Sports and Recreation. Laser rangefinders are employed in sports such as golfing, hunting, and shooting to provide precise distance measurements. They enhance accuracy and performance, enabling athletes and enthusiasts to improve their skills. For example, laser rangefinders are popular among golfers for measuring distances on the course[4]. They help golfers determine the distance to hazards, greens, and other landmarks, enabling better club selection and shot planning. Laser rangefinders are also used in sports like archery, hunting, and shooting for target distance estimation.

2.1.5. Robotics and Automation. Laser rangefinders are essential sensors in robotics and automation systems for object detection, localization, and navigation. They are commonly used in autonomous vehicles, drones, and industrial robots to perceive the surrounding environment and avoid obstacles. Laser rangefinders provide reliable distance measurements for ensuring safe and efficient operations.

2.1.6. Forestry and Environmental Monitoring. Laser rangefinders measure tree height, biomass, and canopy density for forest management and ecological research[5]. They also monitor environmental changes and analyze vegetation patterns. For example, use of laser rangefinders in a forestry research project for accurate measurement of tree parameters [6].

2.1.7. Military and Defense. Laser rangefinders play a crucial role in military operations for targeting and range estimation. They provide accurate distance measurements for effective deployment of weapons and personnel [7]. They are integrated into weapon systems, such as rifles, artillery, and guided missiles, to enhance accuracy and precision. Additionally, laser rangefinders are used in reconnaissance and surveillance systems for target acquisition and intelligence gathering[8].

2.2. Design-based Classification

The design-based classifications are as follows:

2.2.1. Handheld Rangefinders. Handheld laser rangefinders are portable devices used for personal and outdoor applications. They are compact, lightweight, and easy to use, making them popular among outdoor enthusiasts.

2.2.2. Mounted Rangefinders. Mounted laser rangefinders are integrated into vehicles, aircraft, and weapons systems for military and industrial purposes. They provide accurate distance measurements under various operating conditions.

2.2.3. Two Laser Rangefinders with the Most Contrast. Laser rangefinders can be classified into several types based on their operational principles. The two primary classifications are time-of-flight (TOF) and phase-shift rangefinders. TOF rangefinders measure the time it takes for the laser pulse to travel to the target and return, while phase-shift rangefinders analyze the phase difference between the emitted and received laser signals.

3. Operating Principles of Laser Rangefinders

3.1. Time-of-Flight Rangefinders

This type of rangefinder measures the time taken for a laser pulse to travel to the target and back. By knowing the speed of light, the distance can be calculated accurately. They emit a laser pulse towards the target and measure the time it takes for the pulse to return and calculate the distance by multiplying the time by the speed of light [5]. High precision is achieved due to the use of precise time measurement technology, so the accuracy can usually reach the millimeter level. Time-of-flight rangefinders can measure distances quickly, typically at the nanosecond level, making them suitable for applications that require high-speed measurement. Time-of-flight rangefinders can achieve a large measurement distance, far exceeding the range that some other measurement principles can achieve. However, the ability of anti-interference of time-of-flight method is poor, for example, under complex lighting conditions, such as strong sunlight or changes in background light, measurement accuracy can be affected. Compared to other laser rangefinders, the time-of-flight rangefinders have a relatively high cost, especially for applications that require high precision and a wide range.

Overall, the time-of-flight is reliable and high-precision ranging equipment, suitable for occasions that require high precision and large applications, such as robot navigation, industrial automation, and ground measurement. However, it is necessary to consider its advantages and disadvantages based on specific needs and budget.

3.2. Phase-Shift Rangefinders

Triangulation rangefinders determine distance by analyzing the displacement of the reflected laser beam. They emit a laser beam onto the target object and capture the reflected beam using a sensor at a known angle. Phase-shift rangefinders measure the phase difference between the emitted and received laser signals. This phase difference is used to calculate the distance based on the known wavelength of the laser. They measure the phase difference between the emitted and received laser signals and use the phase difference to calculate the distance based on the known wavelength of the laser. Its precision can reach the submicron level. The detection distance in normal scene volume can usually reach meters to tens of meters. Distance measurement within this range is a common application, suitable for industrial automation measurement instruments, remote monitoring, etc. If a larger ranging range is required, it may be necessary to use other laser ranging principles or more advanced measurement techniques.

It is worth noting that accuracy and detection distance do not always increase or decrease in the same way. Increasing the accuracy of laser distance may require higher precision optical devices and instruments, while also considering the influence of environmental factors. Increasing the ranging range may require stronger laser power and higher detection sensitivity. Therefore, in specific applications, the exact accuracy and detection requirements should be evaluated based on the actual situation, and appropriate laser ranging principles and measurement devices should be selected. Phase-shift method

possesses high precision, large measurement range, and the ability to be strong against interference from sound. On the other hand, phase-shift rangefinders depend on the reflection properties and reflectivity of the target surface, they can also be affected by environmental factors like humidity and temperature. Laser rangefinders based on phase measurement principles require more complex equipment and algorithm support, which may pose certain technical difficulties compared to other ranging principles[9].

In general, laser rangefinders based on the principle of phase shift change have a large measurement range and accuracy, but there are also drawbacks such as dependence on the surface properties of the target and environmental conditions. The selection of appropriate laser ranging sensors should be comprehensively considered based on specific application requirements.

3.3. Triangulation Rangefinders

They first emit a laser beam onto the target object. Then, the reflected beam is captured using a sensor at a known angle. Next, the displacement of the reflected beam to determine the distance is analyzed. Triangulation rangefinders have high measurement accuracy and are suitable for application scenarios that require high displacement measurement accuracy. Furthermore, it adopts the non-contact principle, which will not cause physical damage to the target object. In addition, triangulation rangefinders can measure real-time changes in target displacement, making them suitable for application scenarios that require real-time monitoring or feedback. However, whether this kind of rangefinders can operate accurately is depend on the characteristics of reflection of the target surface, for example, if the target surface is too rough or has low reflectivity, it may affect measurement accuracy and reliability. Under strong light irradiation, triangulation rangefinders may be affected by light, which also affects measurement accuracy and stability.

4. Calibration Methods

4.1. Field Calibration

Rangefinders can be adjusted to known reference distances in the field, and the accuracy of the equipment can be verified and fine-tuned under actual conditions. For example, a laser rangefinder can be field calibrated during a measurement program to ensure accurate distance measurements.

4.2. Factory Calibration

Calibration can be performed during the manufacturing process to ensure initial accuracy. Calibration standards and procedures are set by the manufacturer. For example, laser rangefinders are factory calibrated in an industrial environment to meet quality control requirements.

4.3. Periodic Recalibration

Periodic maintenance and recalibration can be performed to maintain accuracy over time. It is recommended at specific time intervals or when the rangefinder shows signs of deviation. For example, laser rangefinders are recalibrated periodically in military applications to ensure consistent and reliable distance measurements [10].

5. Conclusion

Laser rangefinders have revolutionized distance measurement in various fields, offering high precision and efficiency. This paper provides a comprehensive understanding of laser rangefinders, including their classification, operating principles, practical applications, and calibration methods. The classification is divided into different parts according to the different usage, design, principles, calibration. The laser rangefinders can be applied in different fields, the areas of application are described, additionally, how laser rangefinders work in these systems is explained. Then the design of different kinds of laser rangefinders is introduced. Subsequently, the principles that operates laser rangefinders are introduced. The principles are respectively time-of-flight, phase-shift, triangulation. Ultimately is the calibration of

laser rangefinders, this makes laser rangefinders more accurate. Laser rangefinder can lead the investment and technique revolution, for the laser rangefinders have been used in more areas, especially military affairs, which means the government would attach importance to the development of laser rangefinders. On the other hand, the amount of laser rangefinders produced these years have been increased almost exponentially which means the people's need is increasing as more newly invented products are produced, the quality of people's daily life is also being tried to arise. The case studies presented demonstrate their effectiveness and significance in real-world scenarios. However, the accuracy of laser rangefinders are easy to be affected by environmental factors. What's more, laser rangefinders are expensive to manufactured, the components are too intricate to produce so finding new ways to improve efficiency is necessary. Therefore, this paper assumes that specific factory for laser rangefinders can be set up, the efficiency and specialization can be both increased. Continued research and development in laser rangefinder technology will further enhance their capabilities and expand their applications. As the technology of laser rangefinders improves, we can get more accurate data so that human science may also get benefits.

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